Detector Developments, Strategies and Perspectives At ESRF

Heinz Graafsma

People who do the work:

- Detectors Pool: Menhard Kocsis, Marc Diot
- Special Detectors: John Morse, Thierry Martin, Cyril Ponchut, Menhard Kocsis
- Analogue Electronics: Jean-Claude Labiche
- Digital Electronics: Christian Herve
- Software group
- Mechanical engineering group
- Beamline scientists

Topics

- Structure at the ESRF
- Focus points
- Strategies
- High energy and high spatial resolution
- Avalanche Photo Diodes (APD's)
- Gas filled detectors
- New 2 D systems

Structure at the ESRF

- Detector Pool: off the shelf
- Special Detectors: consultation, tests, small developments
- Analogue/Transient elec: Frelon CCD
- Control elec: Specific electronics modules
- Digital elec (CS):Gas filled, drift diodes

Focus points

- High spatial resolution imaging (phosphors)
- Sub-milliseconds imaging (GFD's)
- New 2D systems (a-Si, pixel detectors, CMOS imagers, etc.)
- Beam monitoring
- High count rate 0D detectors (APD's, YAP:Ce).

Strategies

- Separate loan service from development.
- Support comes first, Developments second.
- Concentrate on what has most impact.
- Buy if you can, assemble if you have to, develop if you are allowed to.
- Collaborate: other SR, HEP, Space, Industry,...

HIGH ENERGIES IMAGING

PERFORMANCE

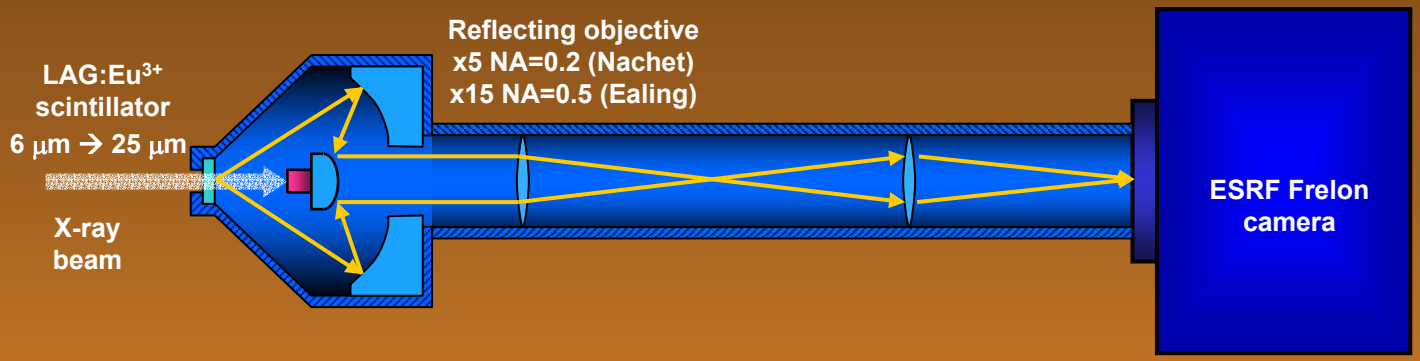
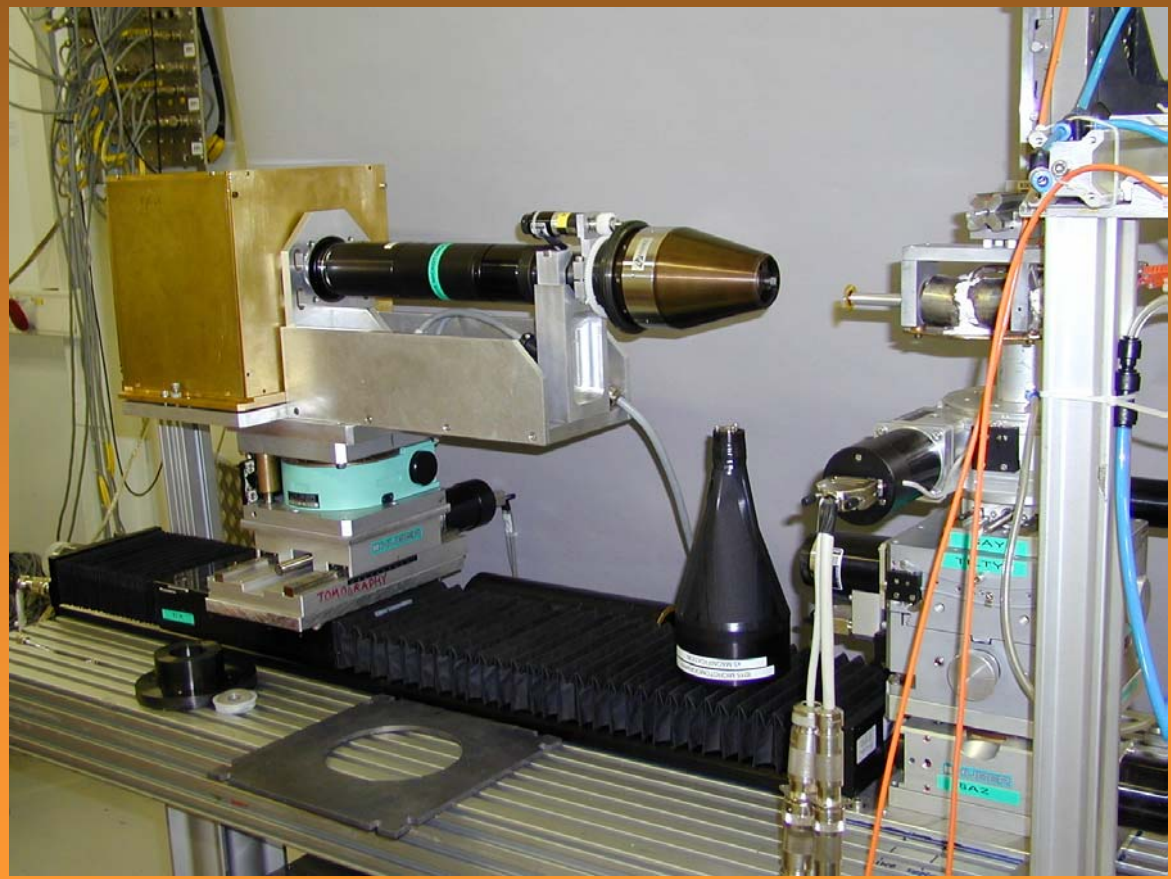


Image depth:	14 bit	Input pixel size:	0.47μm or 1.4 μm
Pixel size:	14 x 14 μm^2	Field of view:	1x1 mm^2 or 2.9x2.9 mm^2
		Spatial resolution:	4μm @ 65keV

Typical acquisition time with kinetic pipeline mode

	Binning	CCD+Exposure(45ms)	Time for 1000 frames
2048 x 128	no	13.6 fps	73 sec
2048 x 256	no	9.7 fps	104 sec
2048 x 256	2x2	13.3 fps	75 sec

DETECTOR on ID15



AVALANCHE PHOTODIODE

Design and construction of a fast counter for X-rays.
Made with Silicon Avalanche PhotoDiode.

- Energy range : 3 keV < $E_{X\text{-}ray}$ < 30 keV (limited by thickness)
- Counting rate: ~ 10^7 cps
- Time resolution: ~ 1ns
- Dark noise: ~ 0.01 cps
- Energy resolution: ~20 % @ 24keV
  ~39% @ 12keV
- Single control module, simple user interface

AVALANCHE PHOTODIODE

ACE (APD Controller Electronic)

7 Heads of detector available

- Hamamatsu
  - Two 5x3mm² 135 μm available
  - ϕ=3mm 135μm (proto)
- EGG
  - Five 5x5mm² 110μm available
  - 10x10mm² 110 μm (future)

Acquisition system : ACE (APD Controller Electronic)

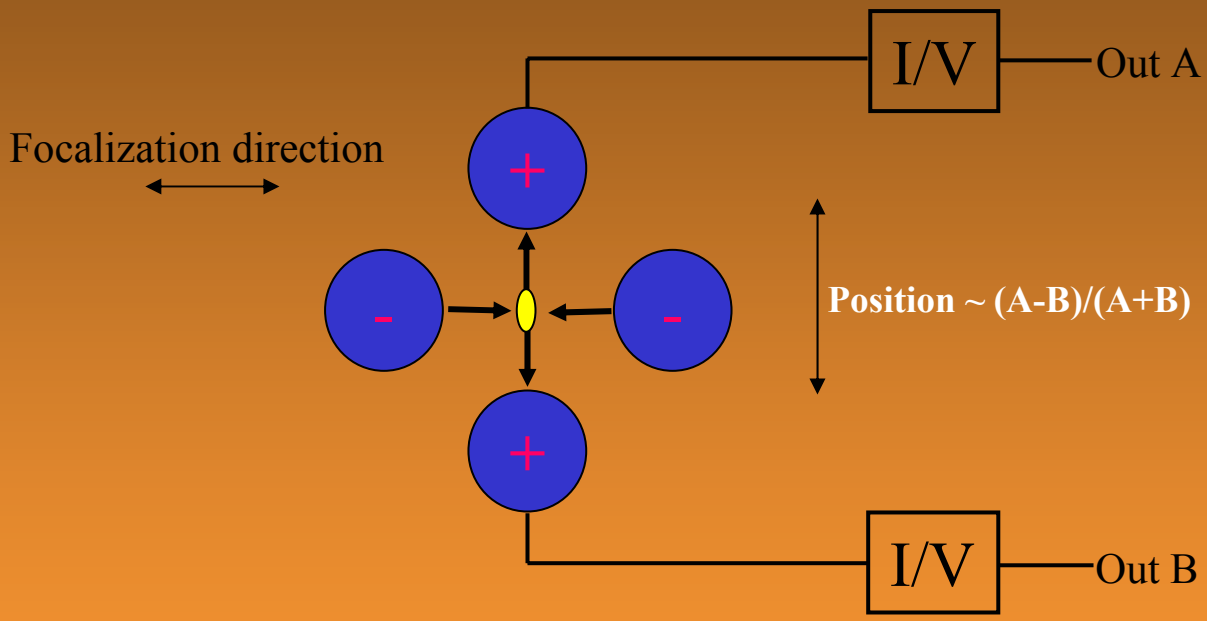
- Principle of use: amplitude (mV) ⇔ energy(eV)
  - 1 counter, 2 thresholds (high and low) for level discrimination
  - Counter with low level only = integral counter.
  - Counter with low-high level = counter in energy range.

GAS-FILLED DETECTORS

- Activities in 2002
  - Development of 1D 10 x 200 mm^2 detector.
  - Micro-ionization chambers.
  - Further development of GEM technology (with CERN)

- Ongoing projects
  - Collaboration in development of Parallel DAQ based 2D detectors.
  - Position sensitive ionization chambers for beam position monitoring.
    - →Obtained μm sensitivity with quadrupole chamber

Position sensitive quadrupole ionization chamber



Separated electron/ion trajectories → lower recombination and space charge
Sensitive *only* to one direction
Simple and robust construction

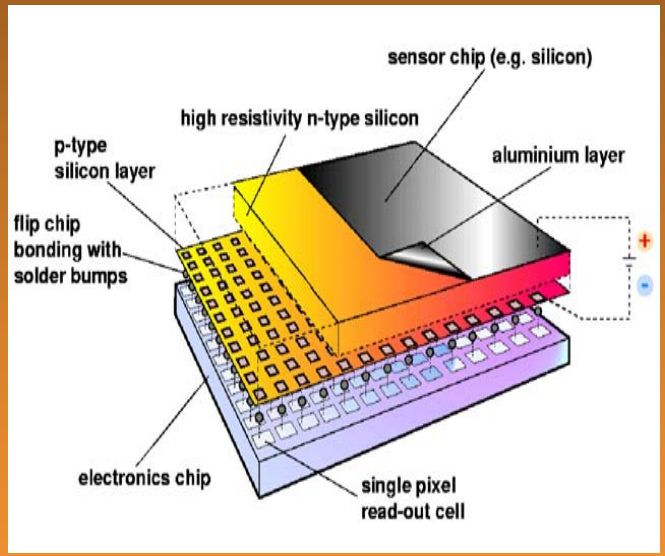
PIXEL DETECTORS: MEDIPIX

Medipix is a collaborative project managed by CERN and involving several European institutes

The Medipix collaboration develops single photon counting area detector prototypes and evaluates them in :

- medical imaging
- non-destructive testing
- materials science
- nuclear decommissionning / gamma imaging

The ESRF joined the Medipix collaboration in August 2000



64x64 square pixels, 170 µm pitch
1.18 cm^2 sensitive area

PIXEL DETECTORS: MEDIPIX

SAXS: ID10

Beam : 8.12 keV, 20x20 µm

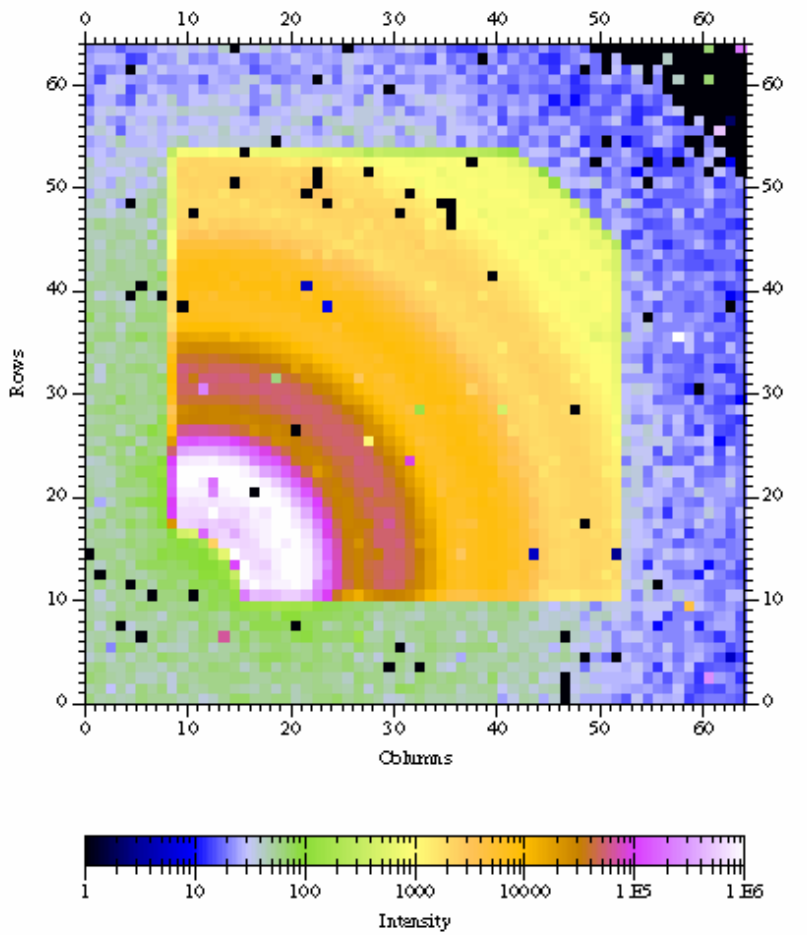
Sample : PMMA colloidal suspension

Acquisition : 100 x 0.2 sec exposures

Processing : dark subtraction

Maximum flux/pixel ~ 10^5 photons/s

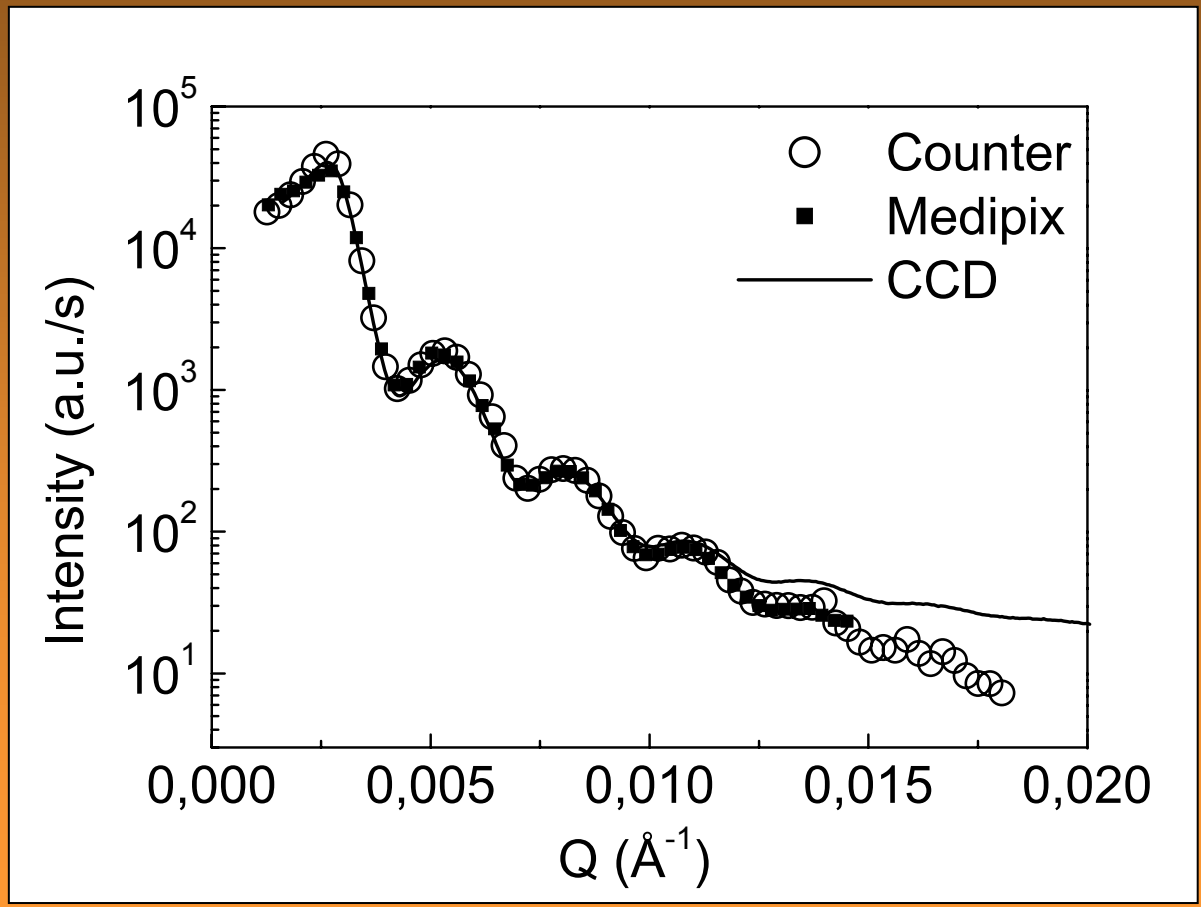
6 orders of magnitude detected



PIXEL DETECTORS: MEDIPIX

SAXS : comparison Medipix/CCD/counter

Exposure times	
Medipix	20 s
Counter	30 min.
CCD	100 s



PIXEL DETECTORS

Ongoing Activities: IDEPHIX

Integrated project proposal for European funding:

- Medical Imaging
- Non-destructive testing
- Safety inspection
- Synchrotron Radiation Science

CERN, ESRF, PSI …..

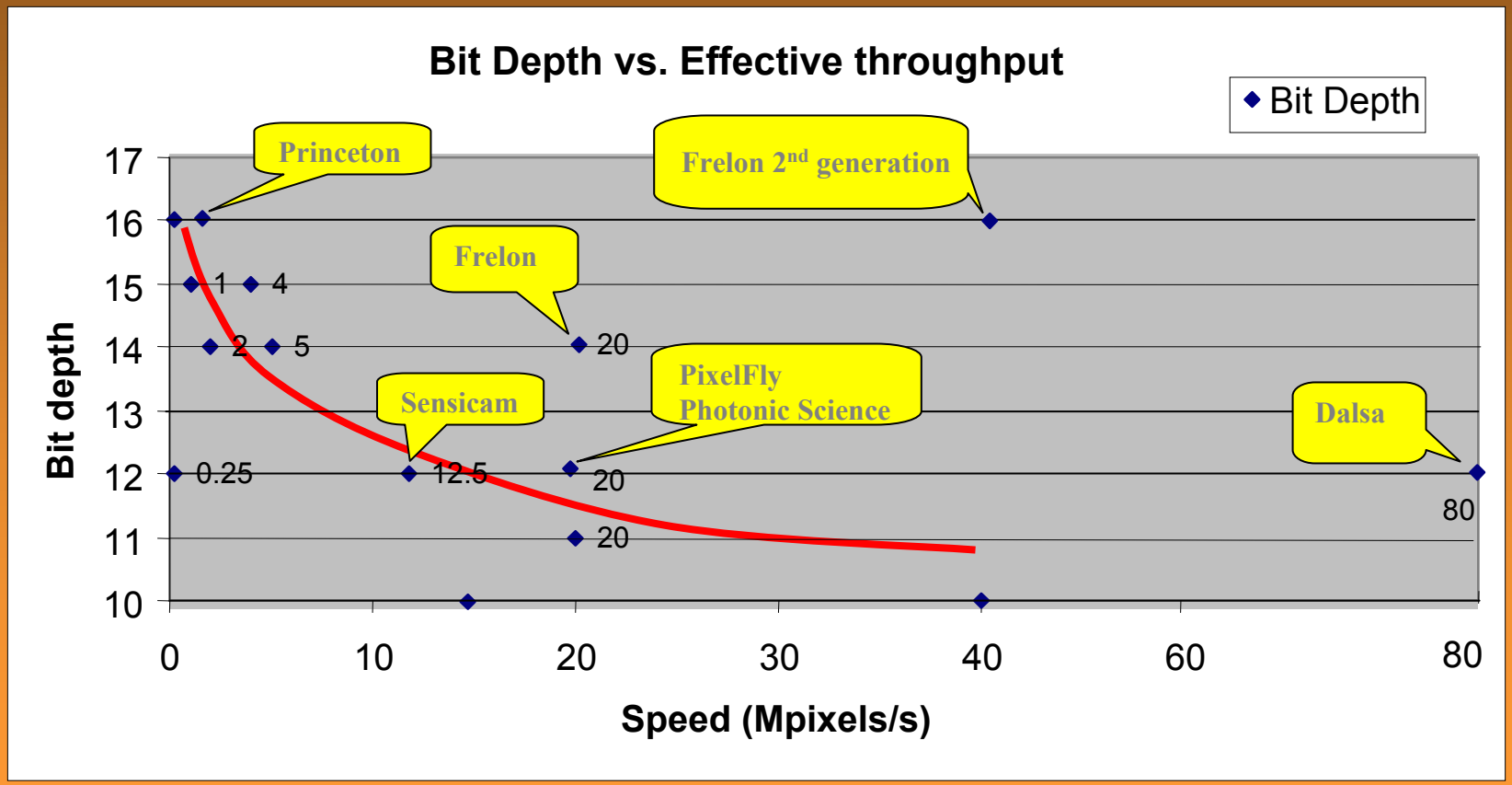
TEST OF CCD CAMERA DALSA: 1M60

Characteristics	Measured
Number of pixels	1024 x 1024
Pixel size	14 x 14 μm^2
Dark current	452 e^-/pixel/sec @ 25°C
A/D converter	12 bit @ 4 x 20Mhz
Gain	50 e^-/ADU
Dynamic Range	12 bit
Saturation	4095
Full Well capacity	204750 e^-
Readout noise	0.96 ADU
Readout time	60 fps
Storage	13sec → 800 frames

ANALOGUE AND TRANSIENT ELECTRONICS:

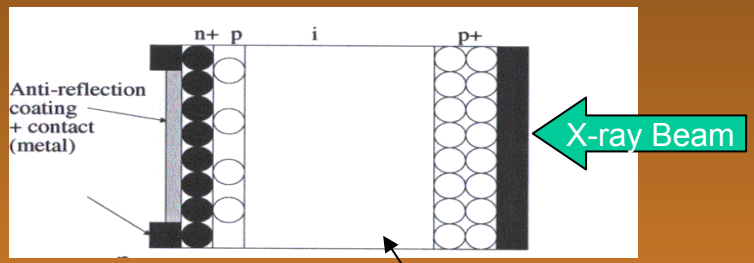
CCD CAMERA

Scientific camera at ESRF

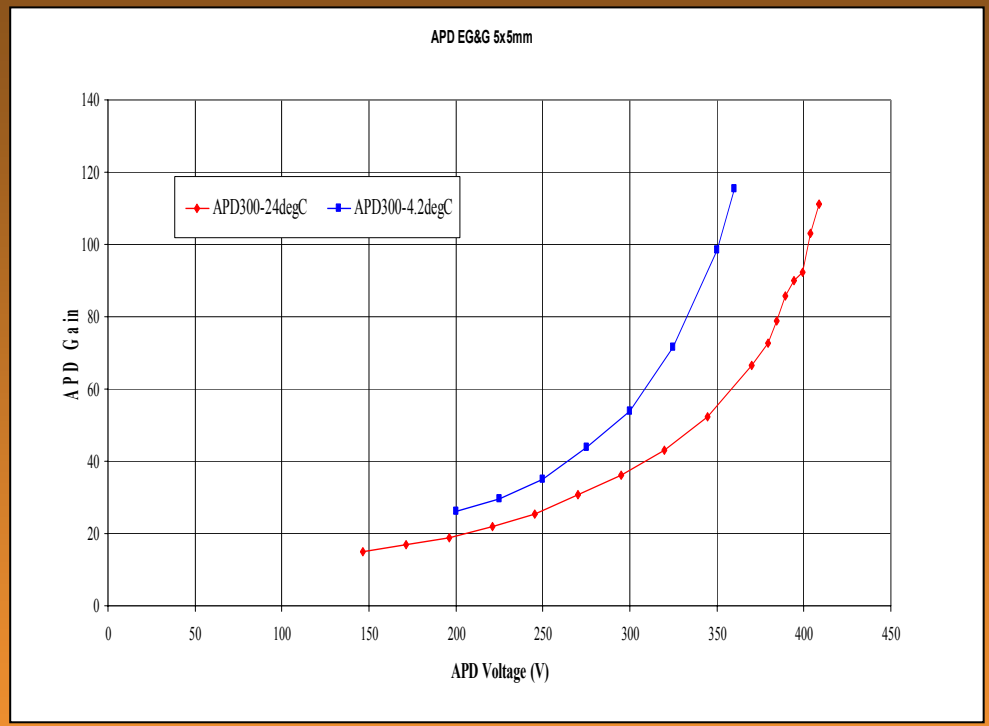


AVALANCHE PHOTODIODE

Real device
"Reach-Through" APD



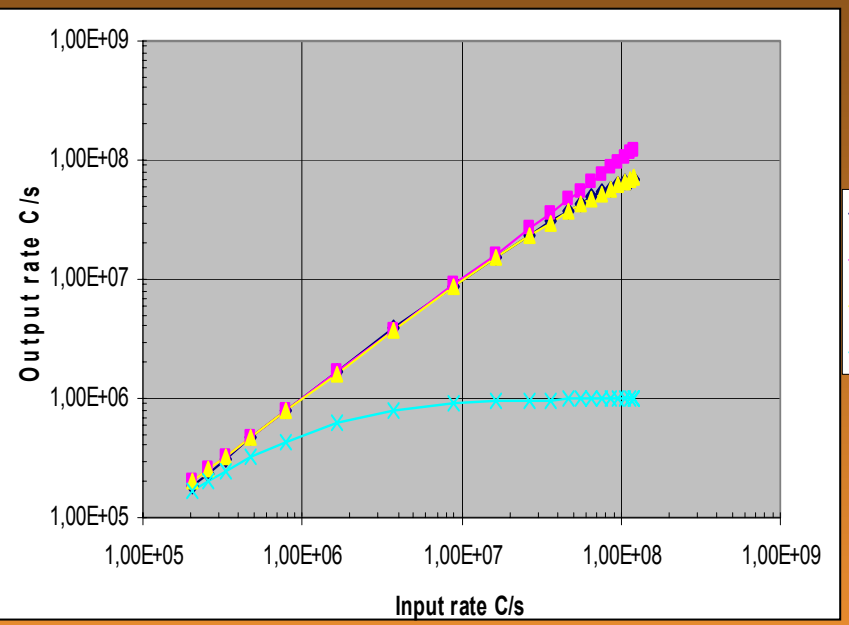
Avalanche region Drift region



APD ≠ pin → *Internal Gain*

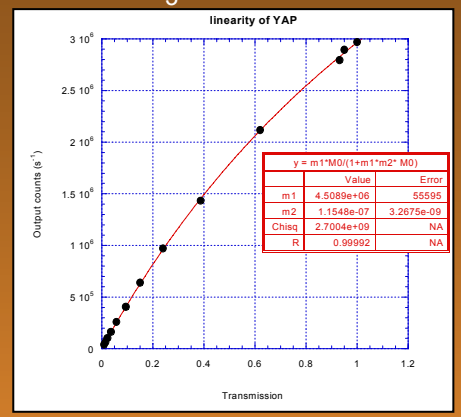
AVALANCHE PHOTODIODE

Comparison of APD to Yttrium Aluminium Oxide Perovskite (YAP:Ce) scintillator cyberstar



@12.5 KeV Hamamatsu 5x3mm² 5.68ns nonparalyzable model using log scales compare to 1us NaI/PMT dead time.

$YAlO_3$:Ce scintillator



	NaI(Tl)	YAP:Ce	APD
Availability	old	May 2003	May 2003
Active area	5cm²	5cm²	0.15cm²
Energy range	5keV…	20…60keV	3…30keV
Energy resolution @ 22keV	28%	44%	30%
Dynamic with dead time correction	400Khz	2Mhz	50Mhz
Dead time	1μs	0.11μs	0.006 μs

ANALOGUE AND TRANSIENT ELECTRONICS: FRELON CAMERA

- Main achievements in 2002
  - Validation of concept for 2nd generation FRELON 16 bit (25000 grey levels), 40Mpixels/sec using DSP.
  - Design of a fast data acquisition board (2 Gbit/s serial data rate) dedicated to the 2nd generation FRELON. Possibility to extend to Dalsa camera.
  - In-house know-how: Gluing of one Taper on a CCD sensor (collaboration with J.Y. Massonnat Optics Group).
  - Kinetic Mode: 250fps for 16 lines: ID15,ID17.
- Ongoing Activities: FRELON 2nd generation
  - 2 prototypes for the end of 2003.
  - Ongoing purchase of 2 new tapers ~ 100 x 100 mm^2 (collaboration with ADSC).
- Camera on Beamline
  - 1k x 1k: ID11, ID19, probably ID22
  - 2k x 2k: BM5, ID2, ID13, ID17, ID19, ID22
  - Spares: two 1kx1k cameras, no 2kx2k camera

ANALOGUE AND TRANSIENT ELECTRONICS:

Comparison of FRELON to DALSA CAMERA

Characteristics	FRELON	DALSA
Number of pixels	2048 x 2048	1024 x 1024
Pixel size	14 x 14 μm^2	14 x 14 μm^2
Dark current	3 e^-/pixel/sec @ -20°C	452 e^-/pixel/sec @ 25°C
A/D converter	14 bit @ 4 x 5Mhz	12 bit @ 4 x 20Mhz
Gain	20 e^-/ADU	50 e^-/ADU
Dynamic Range	14 bit	12 bit
Saturation	16383	4095
Full Well capacity	320000 e^-	204750 e^-
Readout noise	1 ADU	0.96 ADU
Readout time	5 fps	60 fps
Storage		13sec → 800 frames

PIXEL DETECTORS: MEDIPIX

Ongoing Activities: Medipix-2

Medipix-1

Readout chip:

- 64x64 square pixels, 170 μm pitch
- Variable threshold
- 2 MHz/pixel count rate
- 15 bit counters
- Pixel threshold tuning

X-ray sensor:

- 1.18 cm^2 sensitive area

Medipix-2

Readout chip:

- 256 x 256 pixels, 55x55 μm pitch
- Energy windowing (2 thresholds)
- Positive or negative pulses (compatible with Si, CdTe, AsGa,…sensors)
- 1 MHz count rate
- 13 bit counters

X-ray sensor:

- 1.98cm^2 sensitive area

Status

•First X-ray tests made at CERN in December 2002

•Tests planned at ESRF in 2003

PIXEL DETECTORS: MEDIPIX

^{55}Fe source (5.9 keV, 6.4 keV)

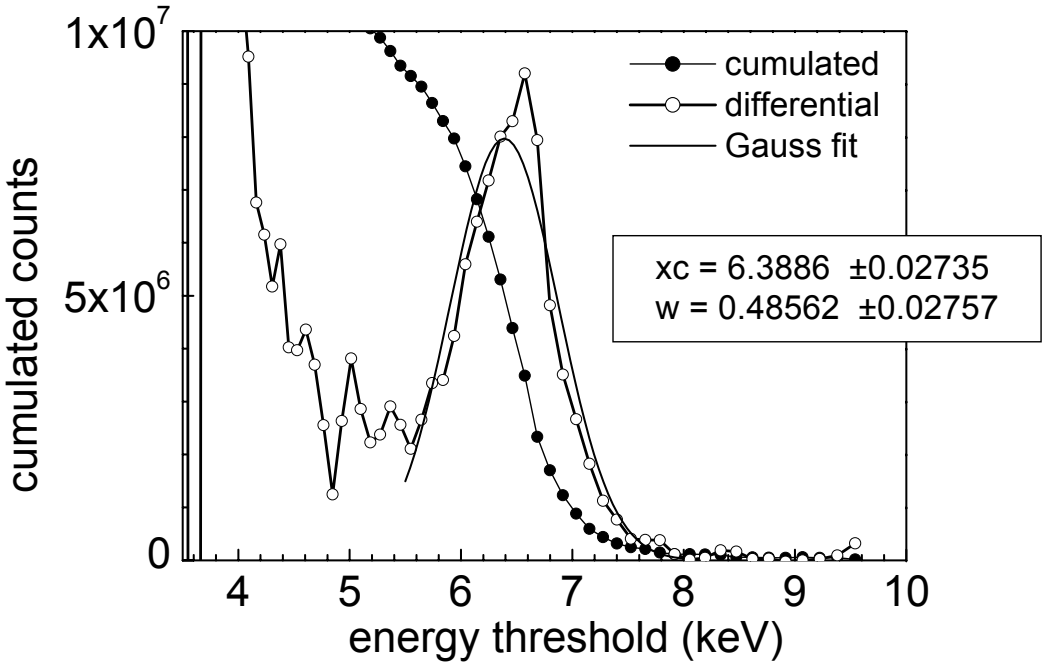
Vth steps : 5 mV

Exposure time : 10 s

Summing over all pixels

Low energy calibration mask

Energy resolution: possible

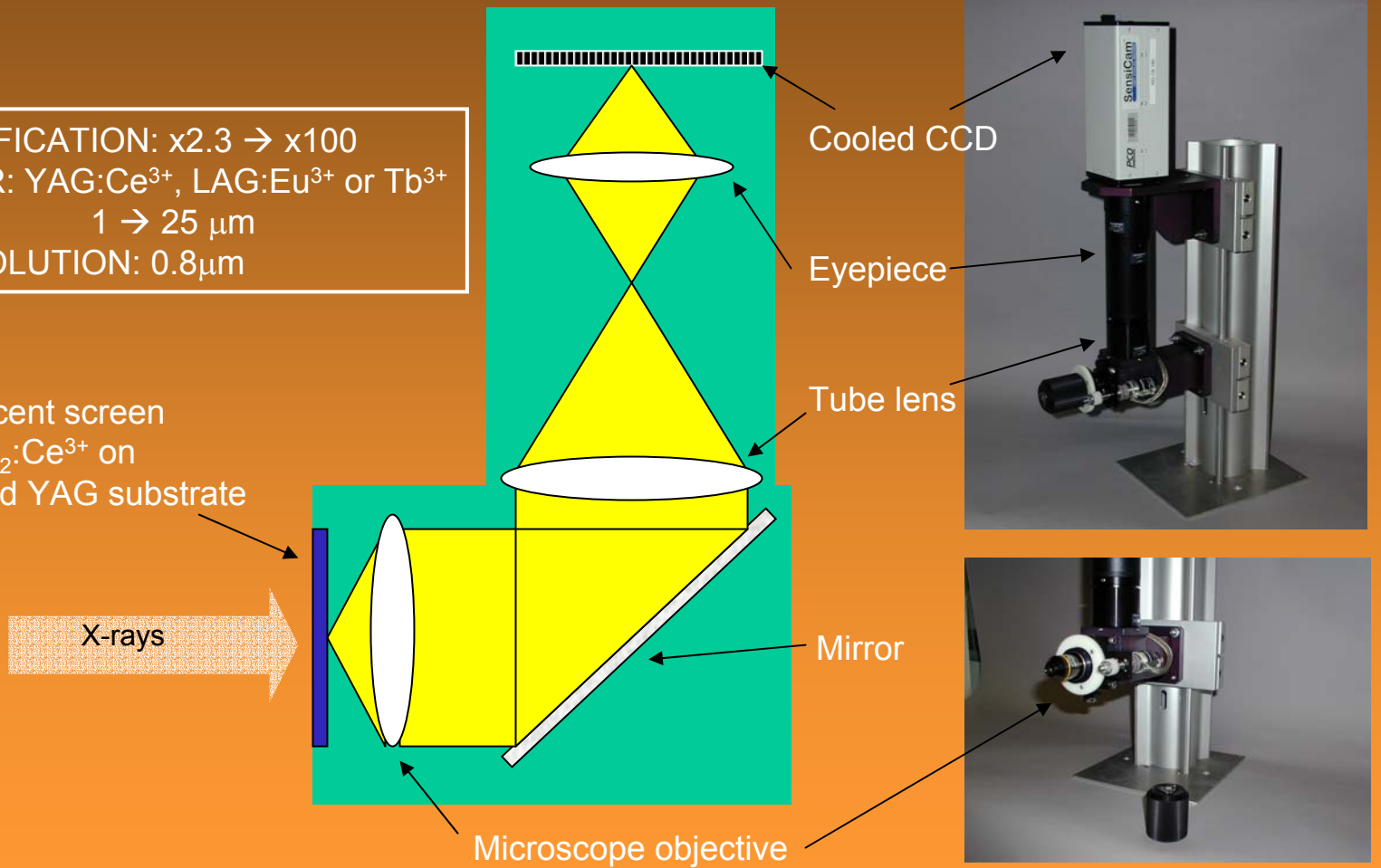


HIGH ENERGIES IMAGING

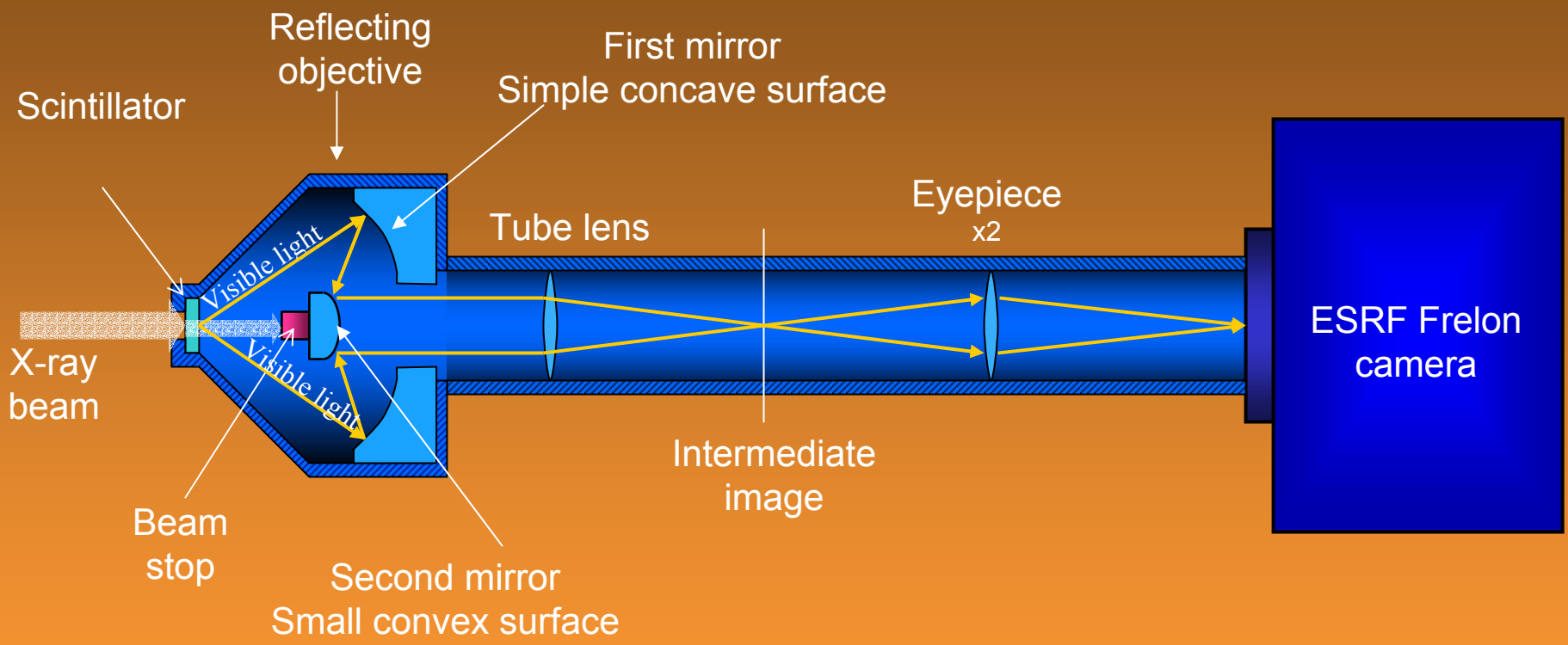
State-of-the-Art

FOLDED DETECTOR for Low Energy

- TOTAL MAGNIFICATION: x2.3 → x100
- SCINTILLATOR: YAG:Ce^{3+}, LAG:Eu^{3+} or Tb^{3+}
  1 → 25 μm
- SPATIAL RESOLUTION: 0.8μm

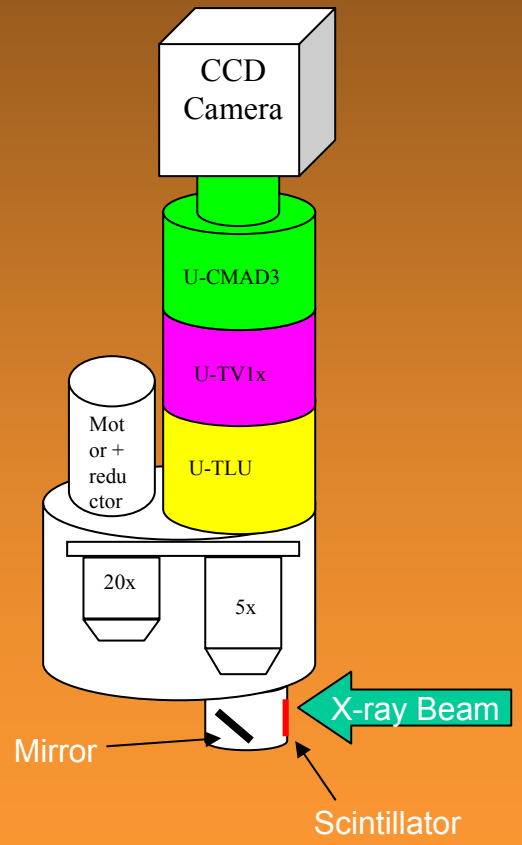


HIGH ENERGIES IMAGING



HIGH ENERGIES IMAGING
Ongoing activities

- New x10 reflecting objective (compromise between magnification and NA)
- Development of high-energy high-resolution imaging systems with 3 motorized zooms for ID11
- Thicker $Lu_2O_3:Eu^{3+}$ and $Gd_2O_3:Eu^{3+}$ scintillator for high energies (PLD)



TEST OF CCD CAMERA DALSA: 1M60

- **Advantages:**
  - **High data rate 60fps**
  - **Low readout noise**
  - **Compact 94 x 94x 102 mm^3**
  - **Good understanding of technical requirements by Dalsa**
  - **Camera for fast tomography**

- **Disadvantages:**
  - **Important dark current→ short exposure time**
  - **Cooling system impossible**
  - **Quality of chip (5 columns defect)**
  - **12 bit**